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Nernst Lamp

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NERNST LAMP

BY

R.E. CUNNINGHAM
AND
N. WILKINSON

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE IN
ELECTRICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

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OF Bachelor of Science in Electrical Engineering.

Morgan Brooks,

HEAD OF DEPARTMENT OF Electrical Engineering.

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PREFACE.

Two, three glower, Nernst Lamps, with globes, and six glower sets, were received from the department, upon which we have made numerous tests. It has been the object throughout these tests to determine the adaptability of this form of lamp for commercial lighting. Lamps were of the indoor type, and to be run with 224 volts, 60 cycle alternating current.

Table of Abbreviations and symbols used:

B-----	Ballast
C - 0-----	Cut out coil.
G-----	Glower
W-----	Watts
I- -----	Current
E-----	Volts
A-----	Ammeter
V-----	Voltmeter
T-----	Terminal
~-----	Periods per sec.
C.P.-----	Candle Power

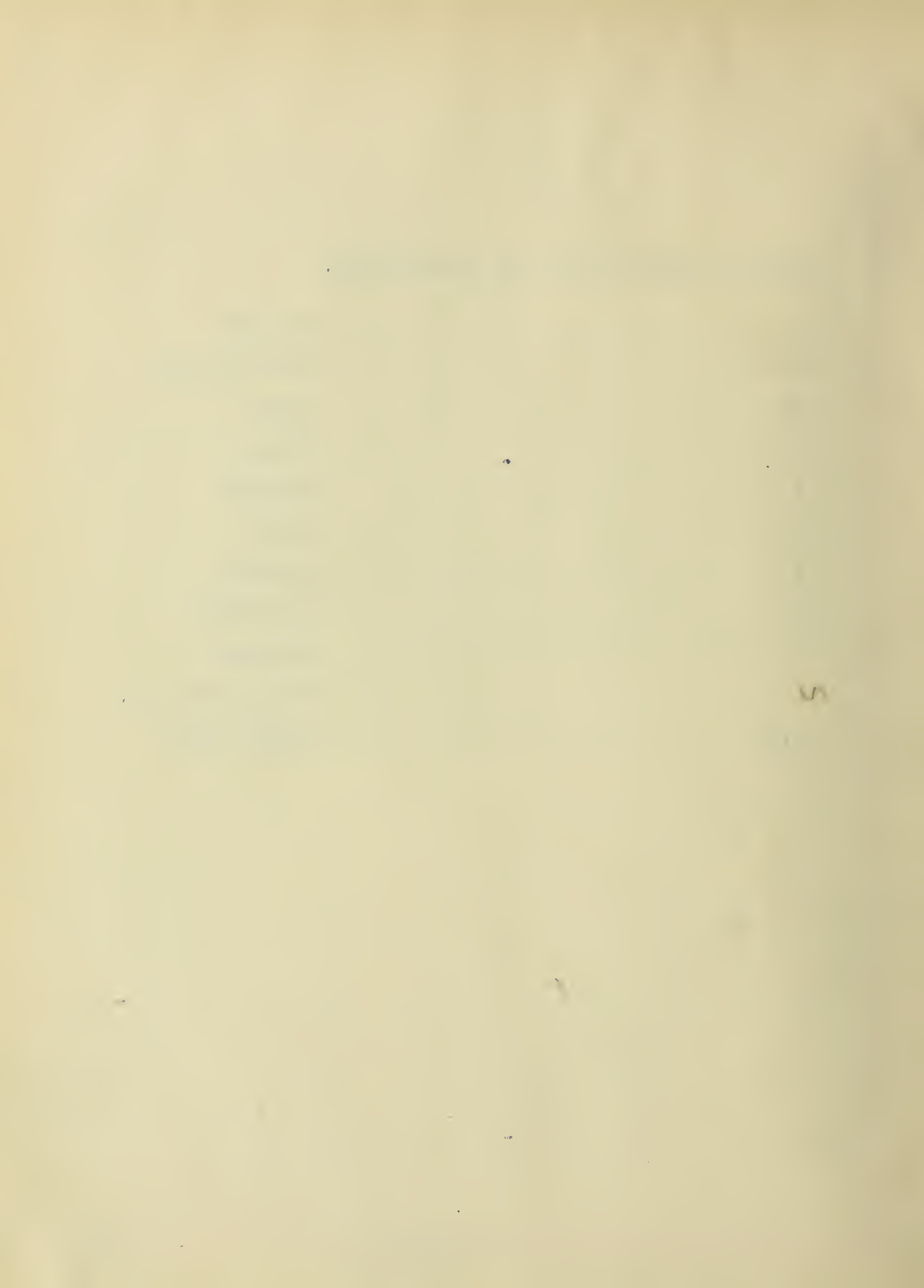


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DISCUSSION

Between the common 16 candle power incandescent lamp, and the socalled 2000 candle power open arc there is a wide gap in the size of the electric light giving unit. To be sure the inclosed arc, taking 6.5 amperes has come in of late, to supply the need of a medium sized unit, having a lessened intrinsic brilliancy and giving better color value and general distribution.

But it is the Nernst lamp which seems destined to fill this gap between the ever ready incandescent and the large unit, arc light. It is obtainable in units of the nominal rating, as follows 50, 100, 170, 400 and 2000 candle power. This type of lamp combines the features of medium efficiency, good color value, intrinsic brilliancy much below that of the arc light, and distribution and lighting effects most pleasing.

The discovery of the Nernst lamp, as its name signifies, we owe to Dr. Nernst. The introduction in America was made by Mr. Westinghouse, the work of development being done by Mr. A. J. Wurts. In 1898 Dr. Nernst exhibited his discovery before Mr. Westinghouse, but on account of the difficulties of its development, it has not been on the market commercially in this country until the beginning of this year.

The essential parts of the lamp in its present commercial form are the glowers, heating coils, ballasts, and cut out apparatus. The ballasts and cutout are placed in the base of the lamp and inclosed in a metal casing. (See Plate 1 and photograph.)

The glowers and heating coils are combined in a separate holder which has projecting terminals, making the proper connections when inserted in place, in the base of the lamp. This arrangement allows a quick and easy renewal of the glowers.

The glower is about 25 millimeters long and .63 millimeters in diameter. To the end of the glower is attached a platinum bead in such a manner that any shrinkage of the glower only tightens the connection. Then to this bead is fastened the leading-in wire. The glower, when cold, is a non-conductor, (its resistance being of the order of 10^7 ohms), but on heating, passes a current. It is also an electrolyte, which property makes it difficult to use with direct current and in the type here described, we found it impractical for use on direct current. The glower performs best in its own air, that is in a globe to which partial circulation of air is allowed. In experimenting with the glower the #manufacturers noted its performance in a vacuum, also in nitrogen, oxygen and hydrogen. In each case better results were found in using air.

As the glower is a non-conductor when cold, there must be a heater which will bring the glower to a proper temperature (950 C) for lighting. This heater consists of platinum wire wound over porcelain tubes. In the 3 glower type there are two heaters located just above the glowers, Connected in series with the glowers is the cut-out coil. When the glowers have been heated sufficiently the current passes through them and energizes the cut-out coil,

The development of the Nernst Lamp in America. A.J. Wurts, A.I.E.E. Vol. 18, p. 511.

which withdraws the contact makers C - C', thus automatically disconnecting the heaters, an ingenious and at the same time simple apparatus.

With the passage of current through the glowers, they rise to a higher and higher temperature, and, contrary to the action of most materials, their resistance becomes less and less, encouraging a still greater flow of current. Were this to continue the glower would flash in a very short time. But right here comes in one of the most unique features of the lamp. It is the ballast resistances one of which is connected in series with each glower. They consist of iron wire of high temperature correction, mounted in a glass tube. This steadying resistance has been so nicely adjusted to the action of the glower that there is no danger of an excessive flow of current.

TESTS

The value of one candle power, to which data throughout these tests refer, was taken from a standard 16 candle power, 110 volt incandescent lamp received from the General Electric Company. An auxiliary working standard, frequently compared with the standard was used during the tests.

In the matter of a photometer we had our choice between the Bunsen and the Lummer Brodhun. On test for accuracy the Bunsen showed the least error and was also found to be less trying to the eyes. Therefore it was used throughout the photometric tests.

A photometer bench three meters in length was employed. At one end and at right angles to the bench was mounted an arm one meter long, capable of being placed at any angle to the horizontal. The end of this arm carried a bracket which held the Nernst Lamp always in a vertical position. At end of bench was a reflecting mirror so pivoted that the rays from the lamp were always thrown directly on the photometer. This arrangement gave an accurate range of working for the photometer when using a 16 C.P. standard, and the lamp could be put in any desired position with respect to the photometer.

All tests except where specially stated, were made with the frosted globe on lamp.

LIFE TEST

Glomers Nos. 1 and 3 were put on life tests. Being supplied from the plant circuit. They were supplied with voltage of good regulation varying less than 3 per cent from normal as shown by recording voltmeter records. By a peculiar coincidence one glower of each of these sets burned out within 48 hours after lighting. Test on No. 1 was discontinued. No. 3 was allowed to burn on for over 500 hours without either of the remaining glowers failing. Test being made frequently for candle power and efficiency. The candle power dropped off in the first 200 hours from 33.5 to 21 per glower, (measurements taken vertically from the lamp and with the frosted globe on) where it remained quite steady, only dropping off one candle power in the last 330 hours. (See life curves).

The Watts per candle power also increased very rapidly at first, starting at 2 and showing 3.5 after 100 hours, where it remained steady for 200 hours and then rapidly increased to 4.2 in the last 200 hours. From this it seems that the lamp is no more efficient than the glow lamp, but the measurements were taken with the frosted globe on, which cuts off $\frac{1}{3}$ of the light by actual measurement. Thus, for 400 hours the lamp used only 2.34 watts per candle power, in a downward direction and with globe on. This would call for a renewal of the glowers after having been burned for 350 or 400 hours, in order to be more efficient than good glow lamps.

TOTAL EFFICIENCY

We tried the method proposed by Nicol in getting at the total efficiency of the lamp, namely, the light energy over the total energy of the lamp. See Plate 4.

A thermopile is set at a certain distance from the lamp and in series a low resistance galvanometer, and the deflection of the galvanometer noted. Then a water screen, which will cut off all the non-luminous rays, is placed between the lamp and thermopile and the deflection noted. This deflection will be proportional to all the luminous rays which pass through the screen. The ratio of light cut off by the screen was measured by the photometer.

NOTE.- In order to get a good deflection for the light energy readings we placed the thermopile near the lamp and inserted a resistance each time the total energy was measured. The thermopile was placed about two feet from the lamp. The readings taken were very consistent. The resistance of the galvanometer used was 16.95 ohms, and that of the thermopile 3.8 ohms.

DISTRIBUTION

The even and pleasing distribution of the lamp is one of its commendable features.

Tests were made with the frosted globe, as furnished with the lamp, with a holophane globe and with globe off. These tests were taken through planes perpendicular to glowers, at 45 degrees, and through the horizontal.

The results of these tests are shown graphically in Plates 6 and 7, where the values are plotted on polar coordinates. Referring to plate 6, we notice the effect produced by using a frosted globe. It tends to smooth out the irregularities of distribution of the lamp without a globe, but at the same time considerably decreases the candle power. At the horizontal, the lamp has scarcely more power than that of one glower, due to the fact that all glowers are in one horizontal place.

The holophane globe used was not specially constructed for this type of lamp, but it shows what might be done in this way to better the horizontal distribution. Something of this kind would be necessary to adapt the lamp for street lighting. It would seem possible that a better arrangement of the glowers might be perfected.

Note:--These curves were taken only through the first and fourth quadrants, and values duplicated in the other two quadrants.

The figures, Plate 7, giving the distribution through the horizontal plane and at 45 degrees, show only what would be naturally supposed. Without the globe, at 90 degrees, the candle power approaches 0, due to the obstruction of the glower supports.

This defect is somewhat remedied by the frosted globe and

scarcely noticeable with the holophane globe.

As lamps are often rated on their mean spherical candle power, this test was made. But in this type of lamp practically the total power of the lamp proceeds from the lower hemisphere. Thus it is only fair that the lamp be rated in accordance. Taking points equally distributed over the lower hemisphere, a value of 56 candle power was obtained.

STARTING CURRENT

When the lamp is first thrown on the circuit and until the glowers light up, the current taken by the lamp goes through numerous and widely varying values. Plate 9 shows this variation, and by it the operations going on within the lamp during the lighting period, are nicely explained. Starting at A the current is flowing in the heater coils and gradually diminishes, due to the increasing resistance of the platinum coils, as they heat up. At B, this has reached a constant value and continues to heat the glowers until, at C, they have reached such a temperature as to pass a small amount of current. This rapidly increases until, at D, it is sufficient to work the cut-out and the glowers light, the current abruptly falling by the amount taken by the heater coils. From E to F the current in the glowers increases, due to the rising temperature and a corresponding decrease of their resistance. This rise would continue, but is checked by the action of the ballast.

Note.— This test was taken with direct current, A. C. instruments not being available for reading the rapid changes of current. Though the values differ slightly in the two cases, the same operations take place.

After lighting some minutes elapse before the lamp assumes a steady condition. This is explained by the fact that when the glowers light they have risen to a high temperature, while the ballast is still cold. Plate 10 shows that after seven minutes the action between glower and ballast has become steady.

VARIATION OF VOLTAGE

A temporary increase of voltage of 10 to 15 per cent of normal, effected no permanent injury to the lamp. Plate 11 shows the effect on candle power and efficiency produced by a variation of voltage.

It was interesting to note the action on the different parts of the lamp, as the terminal voltage was varied. To do this voltmeter leads were brought out from the terminals of each. Plates 12 and 13 show how well the ballast is adjusted to protect the glowers. It was found that the lamp would light at 190 volts but not at 180 volts, and when burning would not cut out the glowers until the voltage fell to 160 volts.

RUNNING ON DIRECT CURRENT

Although the lamp was not designed for direct current this test was made. Plates 14 and 15 show the relative action when using direct and alternating current. The electrolytic action on the glower was very marked. After a few minutes there was a deposit left at the end of the glower, showing a metallic luster. And all the glowers tested broke at this point on second lighting.

THE GYMNASIUM INSTALLATION

Recently 12 of these lamps were placed in the new

Gymnasium of the University of Illinois, to light the main room, (size 100 x 150 feet.) This installation has fulfilled all that was hoped for it. The lamps are hung from the trussed roof, lighting the main room and the suspended running track. Incandescents with frosted globes are used in combination with the Nernst lamps, they being placed around the edge of the track.

The effect produced is a shadowless and pleasing lighting through the large hall. The accompanying photographs give some idea of the effect produced. The twelve three glower lamps being sufficient to light well the 15,000 square feet of floor space.

The photographs serve to show the actinic qualities of the lamp.

CONCLUSION

In conclusion, we can state that as far as our tests have gone, we find no reasons why this lamp should not be adopted in many classes of commercial lighting.

The fact that it may be burnt on 25 alternations would recommend it for lighting where long distance transmission is used, making it necessary to use low frequency.

If renewals are made within 500 hours the matter of efficiency is not prohibitive. At present, renewals are made free of charge by the manufacturers.

The lamp is compact and neat in appearance. Having good color values it will be especially adapted for use in stores.



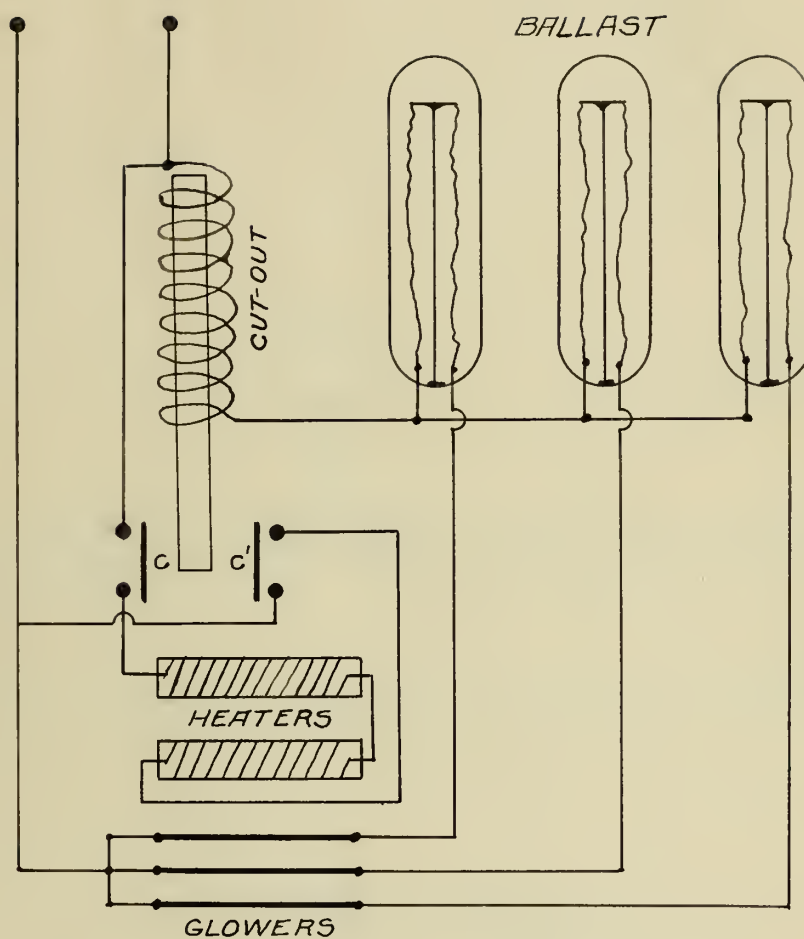
THREE GLOWER, INDOOR TYPE ,
NERNST LAMP.



RUNNING TRACK.



*ARRANGEMENT OF LAMPS IN
NEW GYMNASIUM. UNIVERSITY OF ILLINOIS.*



NERNST LAMP CONNECTIONS.

PLATE-I.

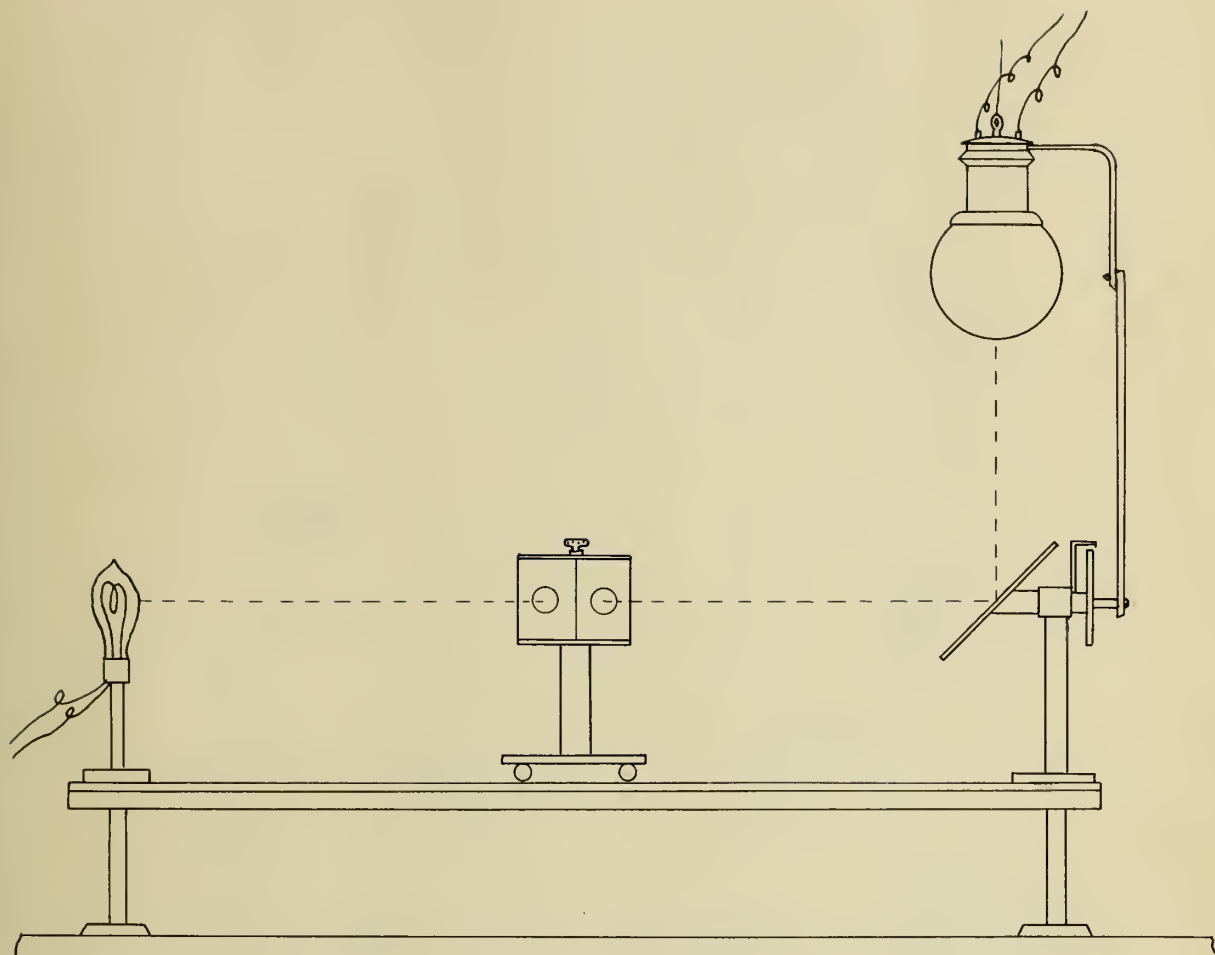
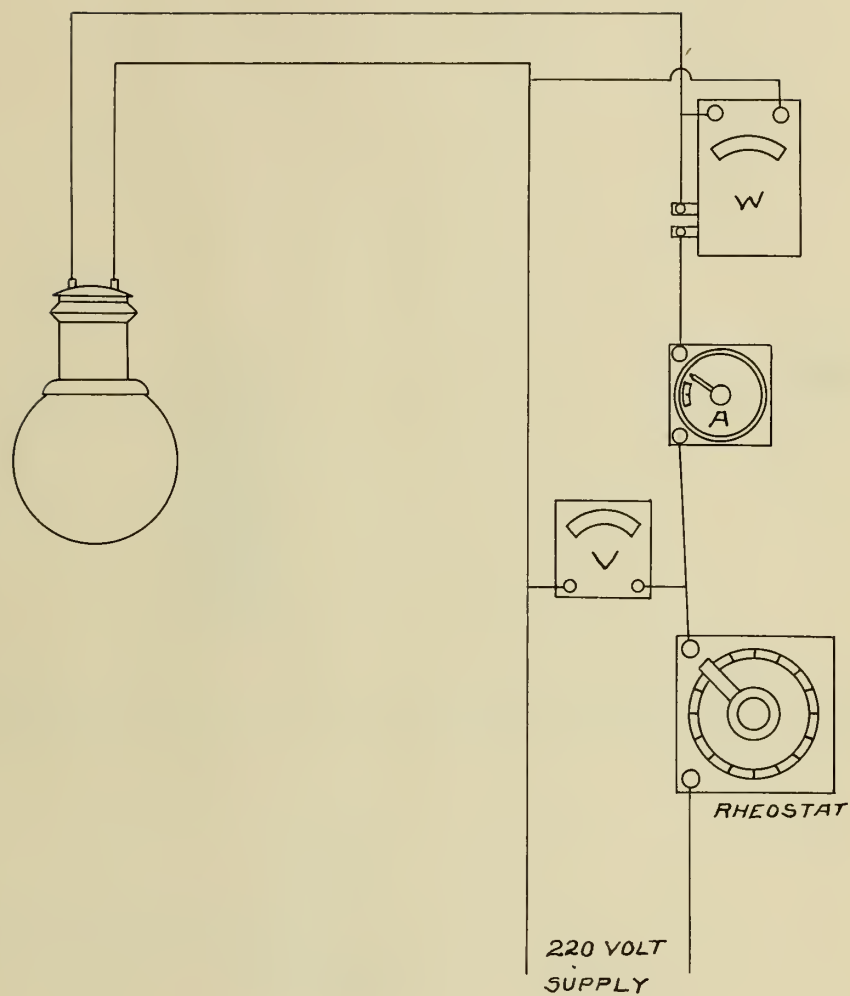


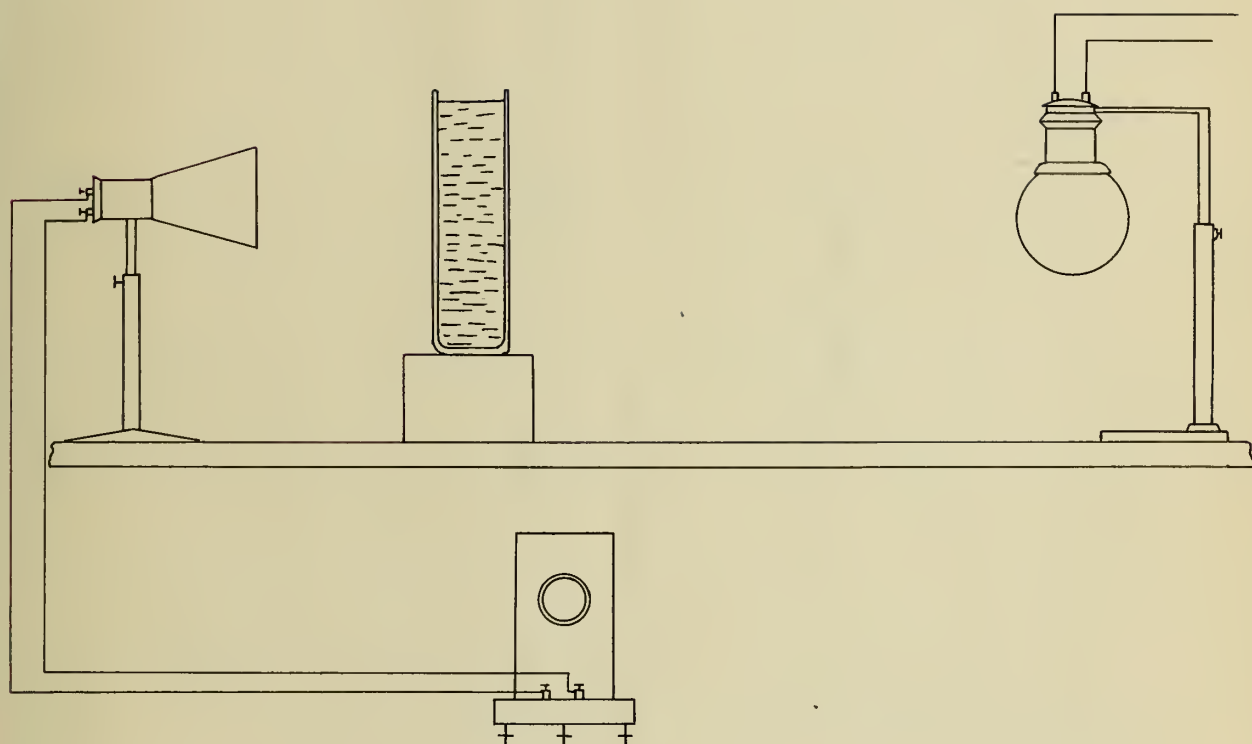
DIAGRAM SHOWING
ARRANGEMENT OF PHOTOMETER BENCH

PLATE - 2.



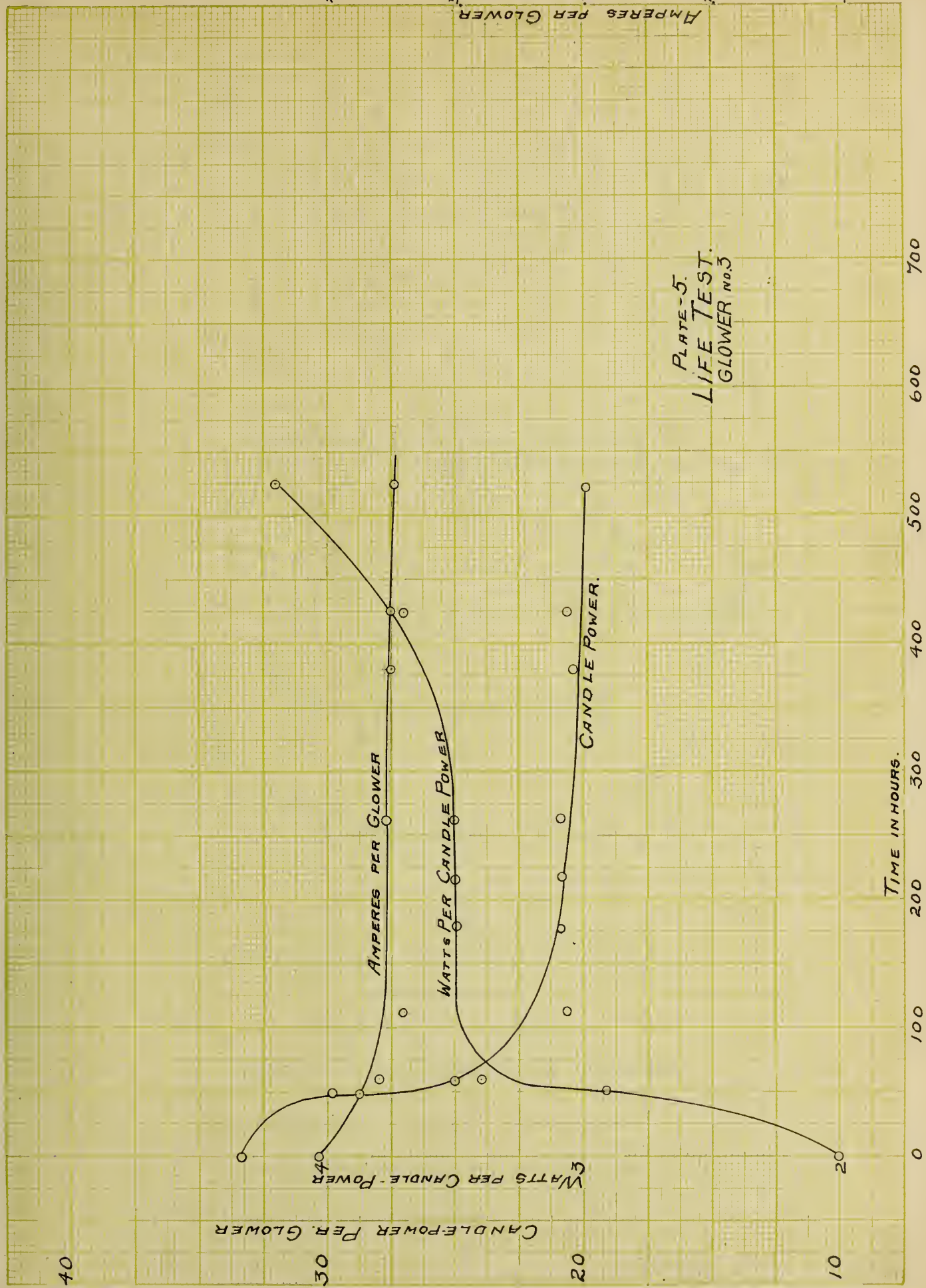
ELECTRICAL CONNECTIONS
FOR TESTS

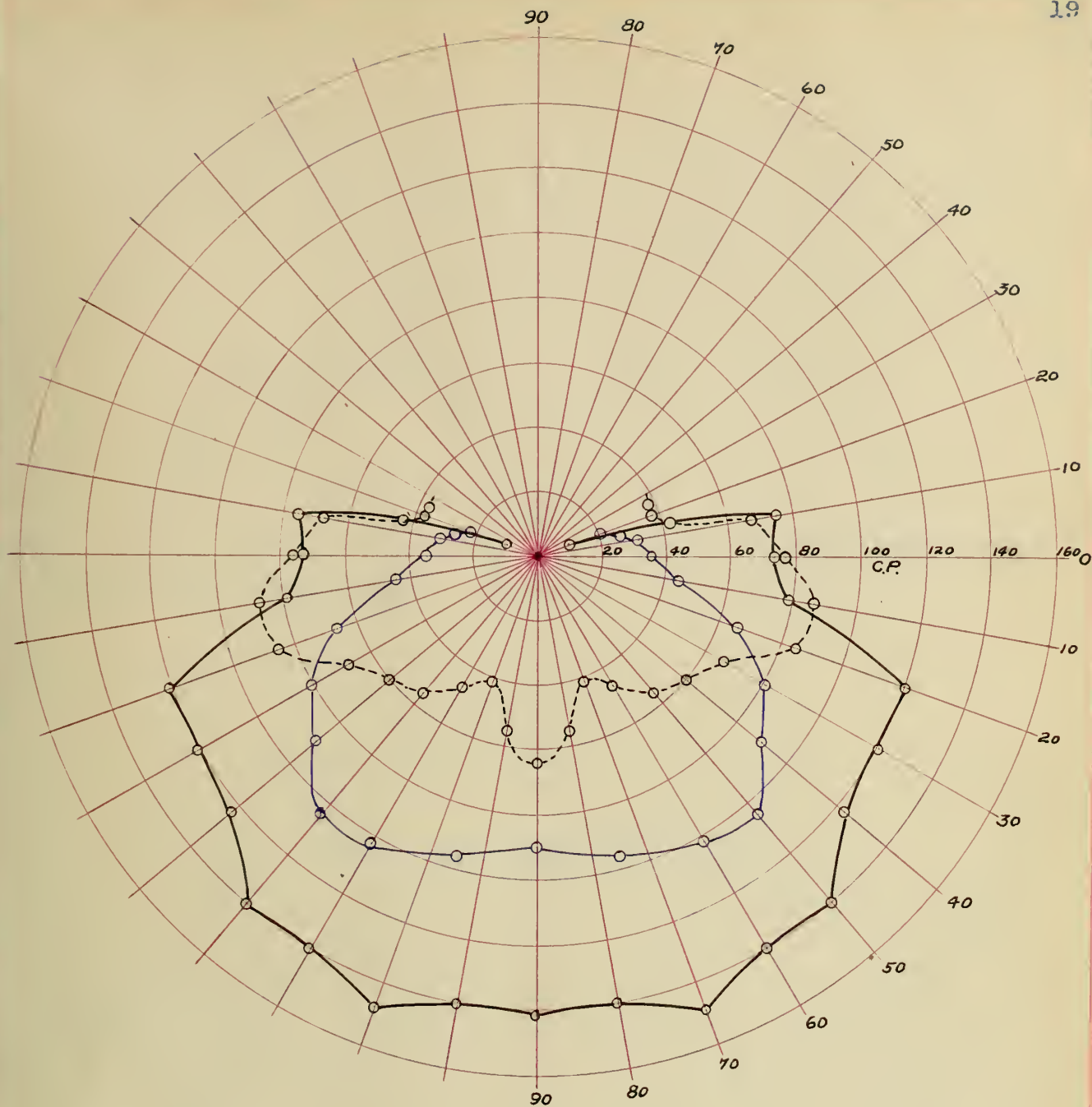
PLATE-3.



*ARRANGEMENT OF APPARATUS
TOTAL EFFICIENCY TEST*

PLATE- 4.





DISTRIBUTION OF CANDLE-POWER

AROUND A

NERNST LAMP

TAKEN PERPENDICULAR TO GLOWERS

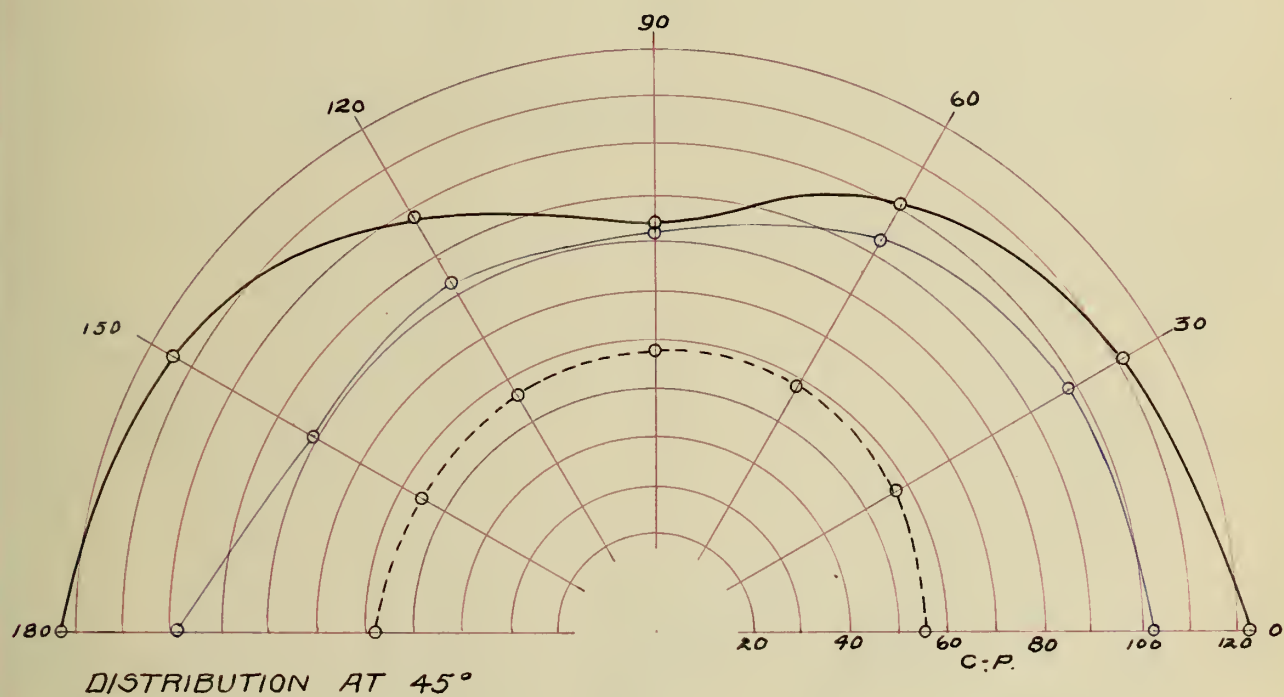
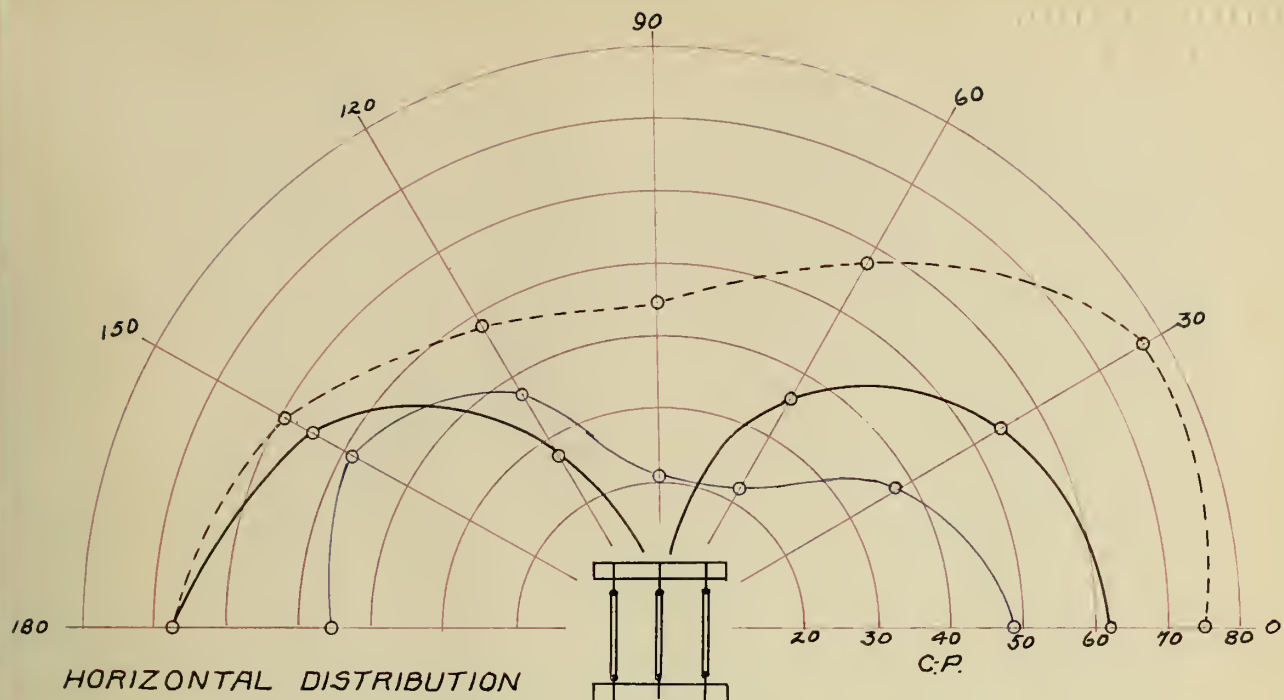
WITHOUT A GLOBE

—————

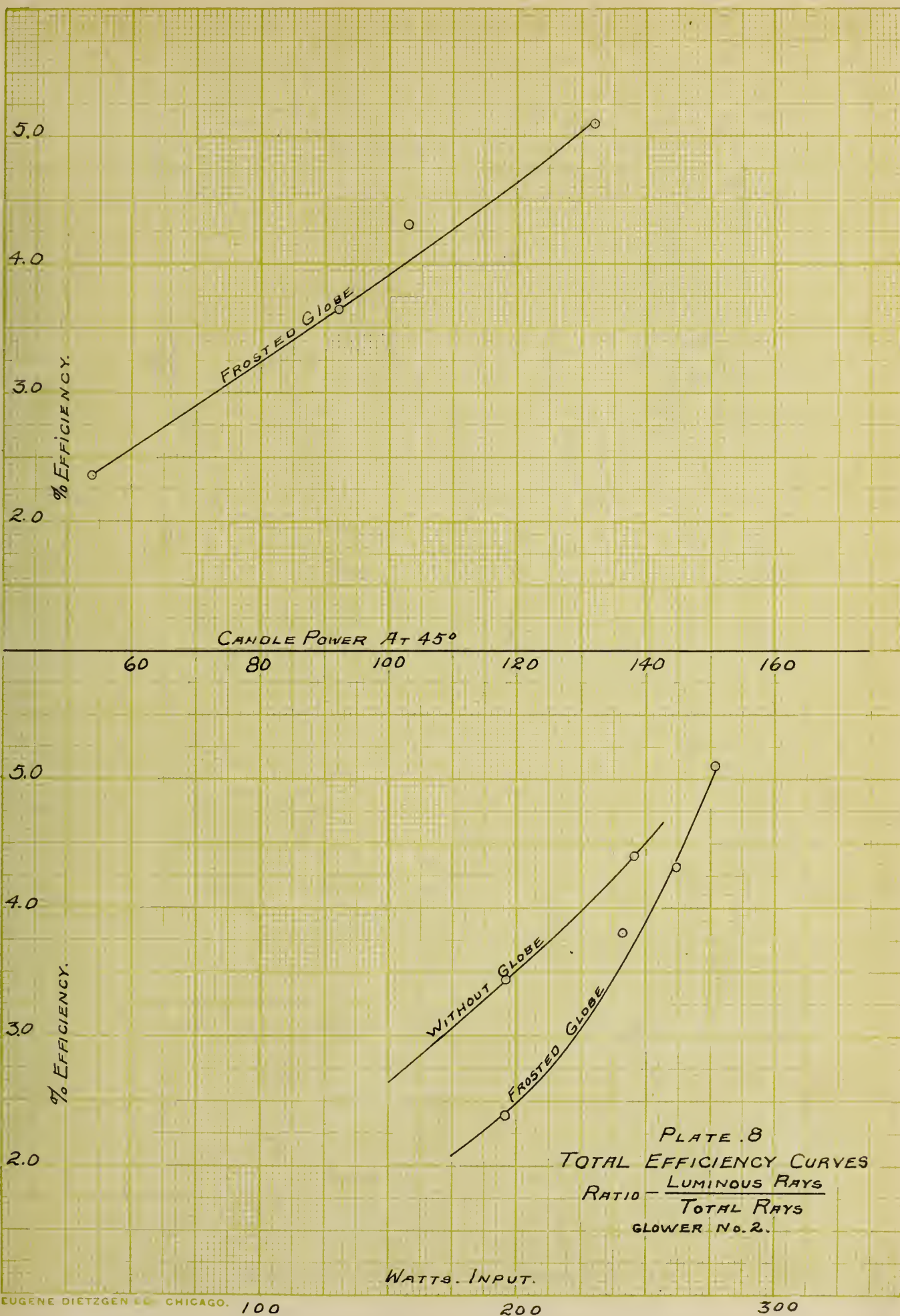
WITH FROSTED GLOBE

—————

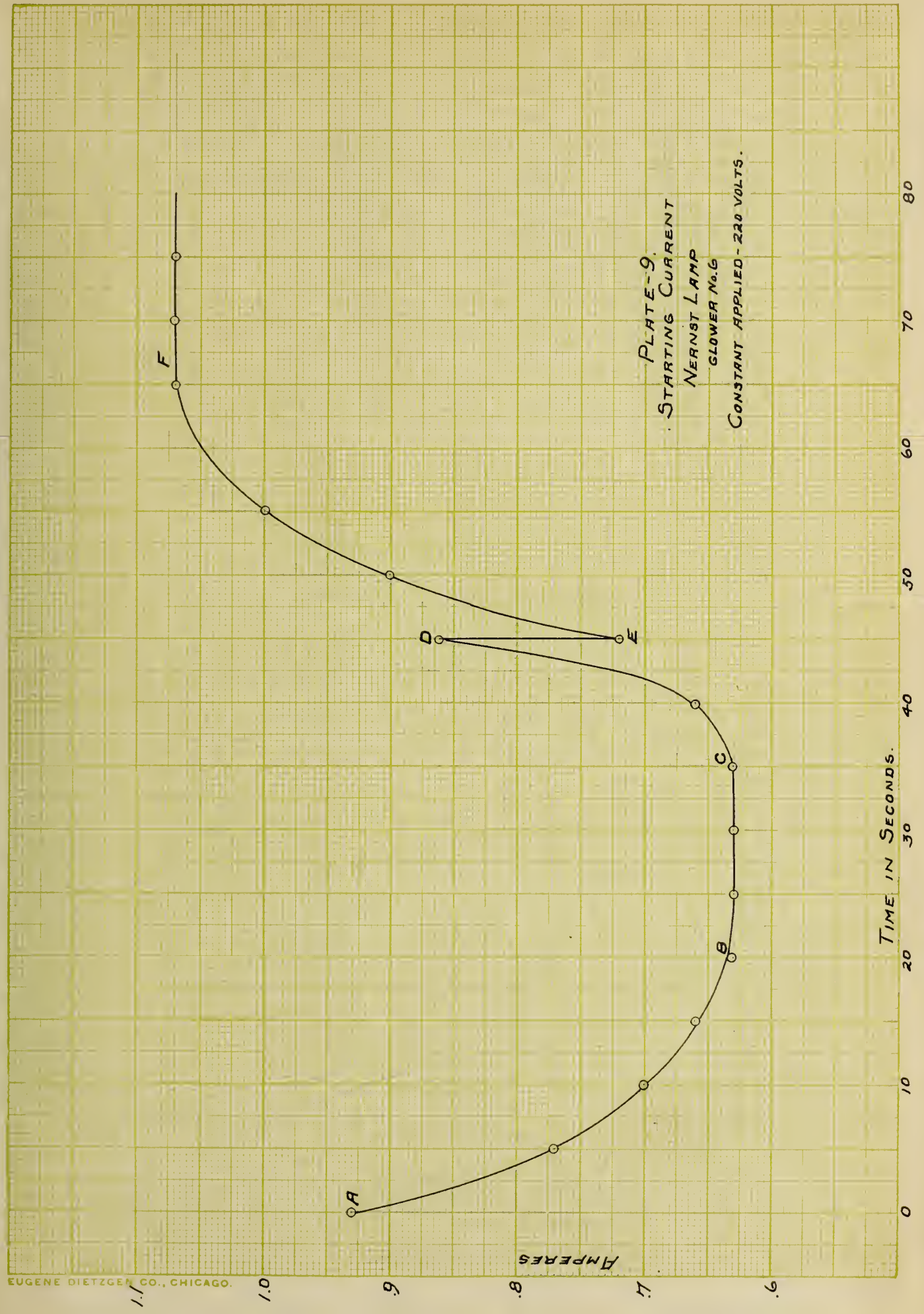
WITH HOLOPHANE GLOBE

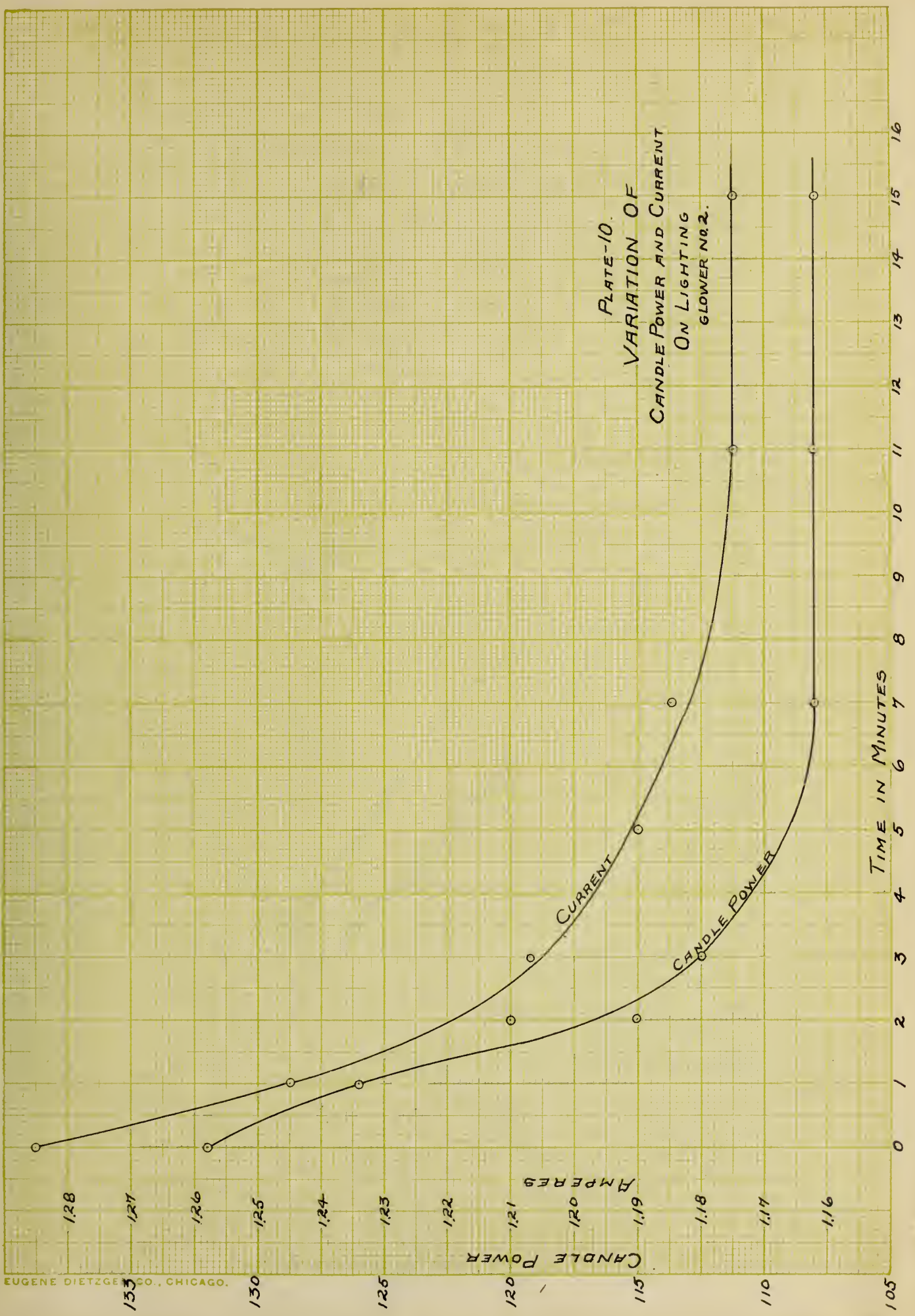


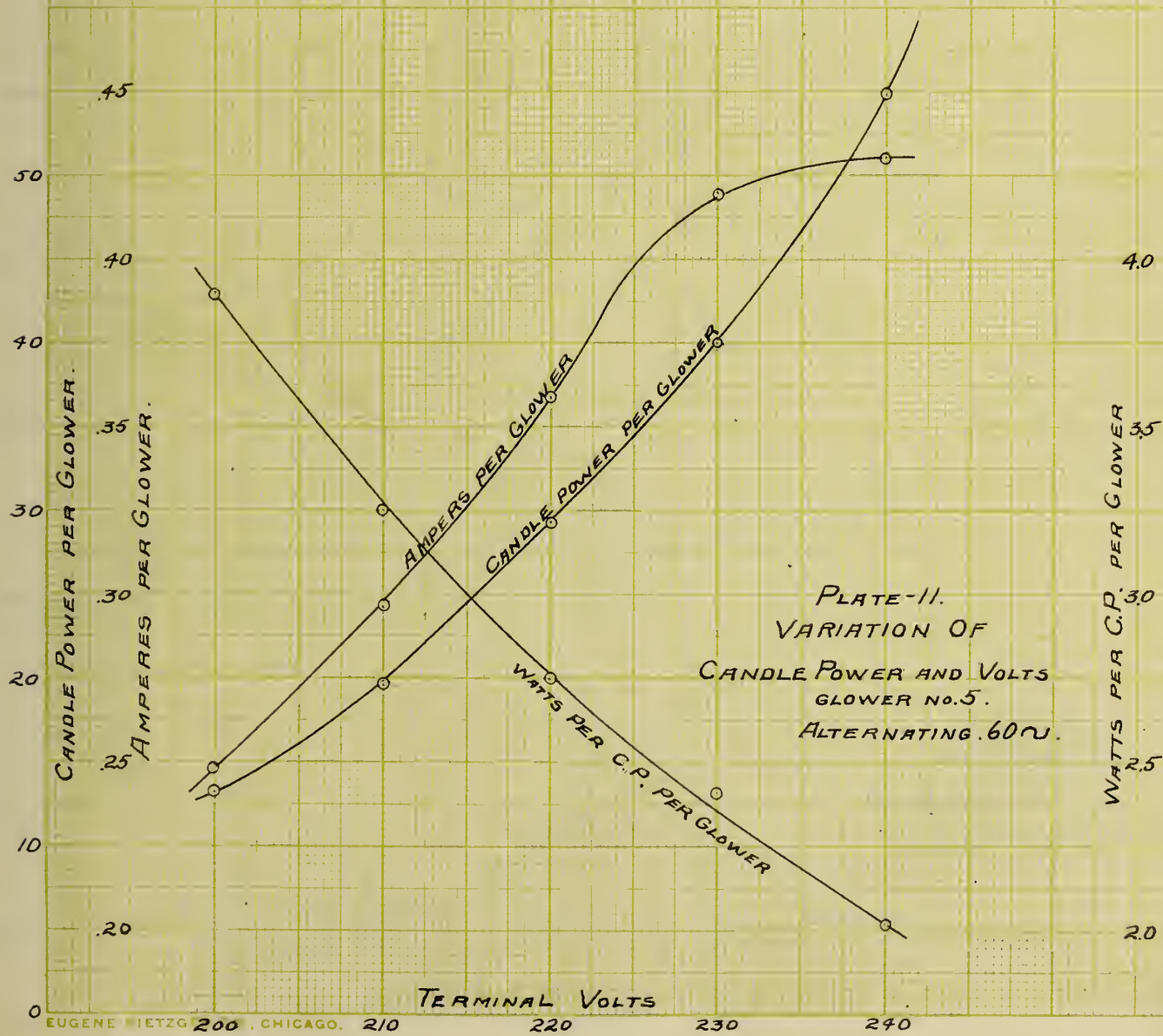
WITHOUT A GLOBE —————
 WITH FROSTED GLOBE —————
 WITH HOLOPHANE GLOBE - - - - -

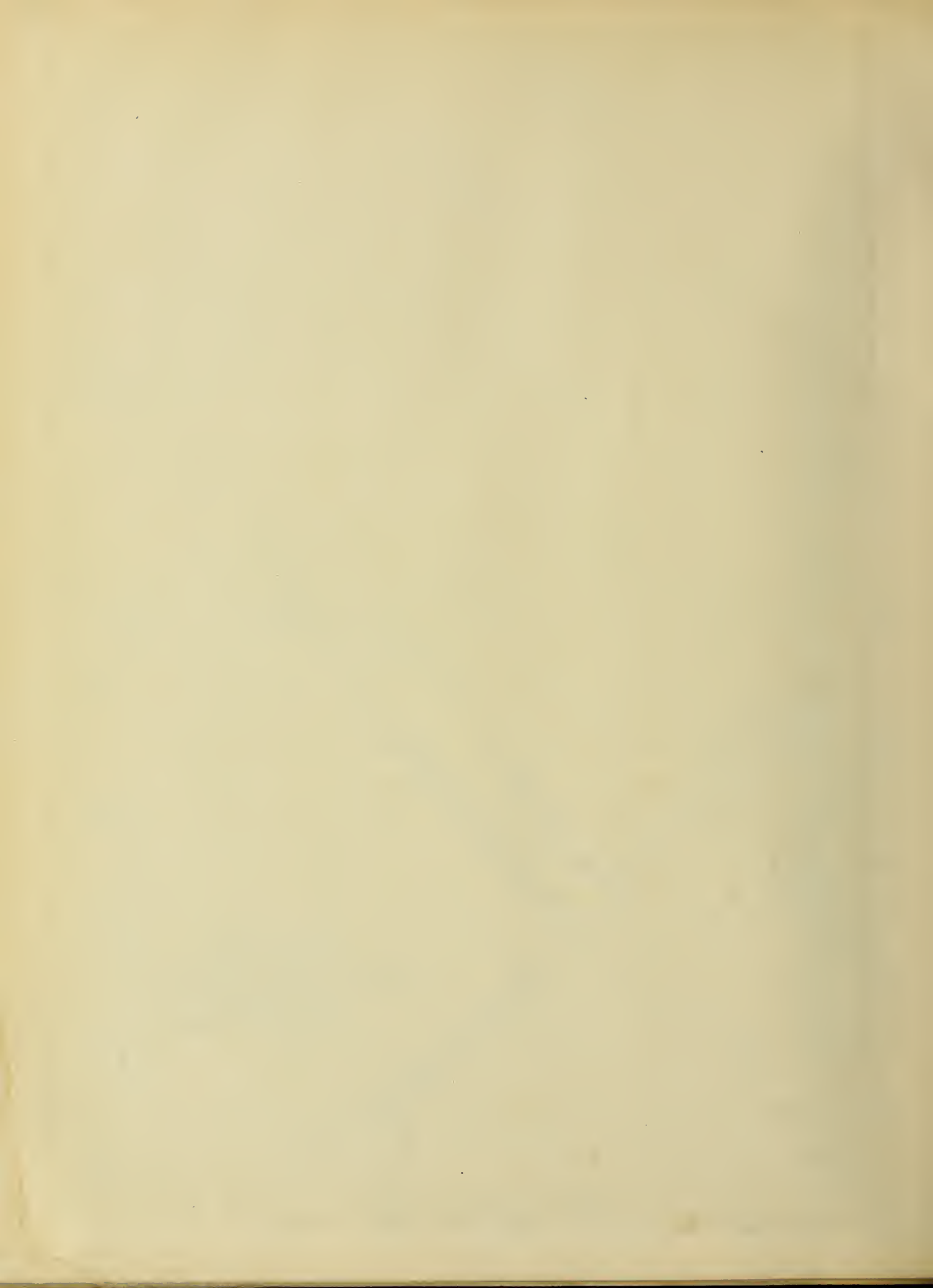


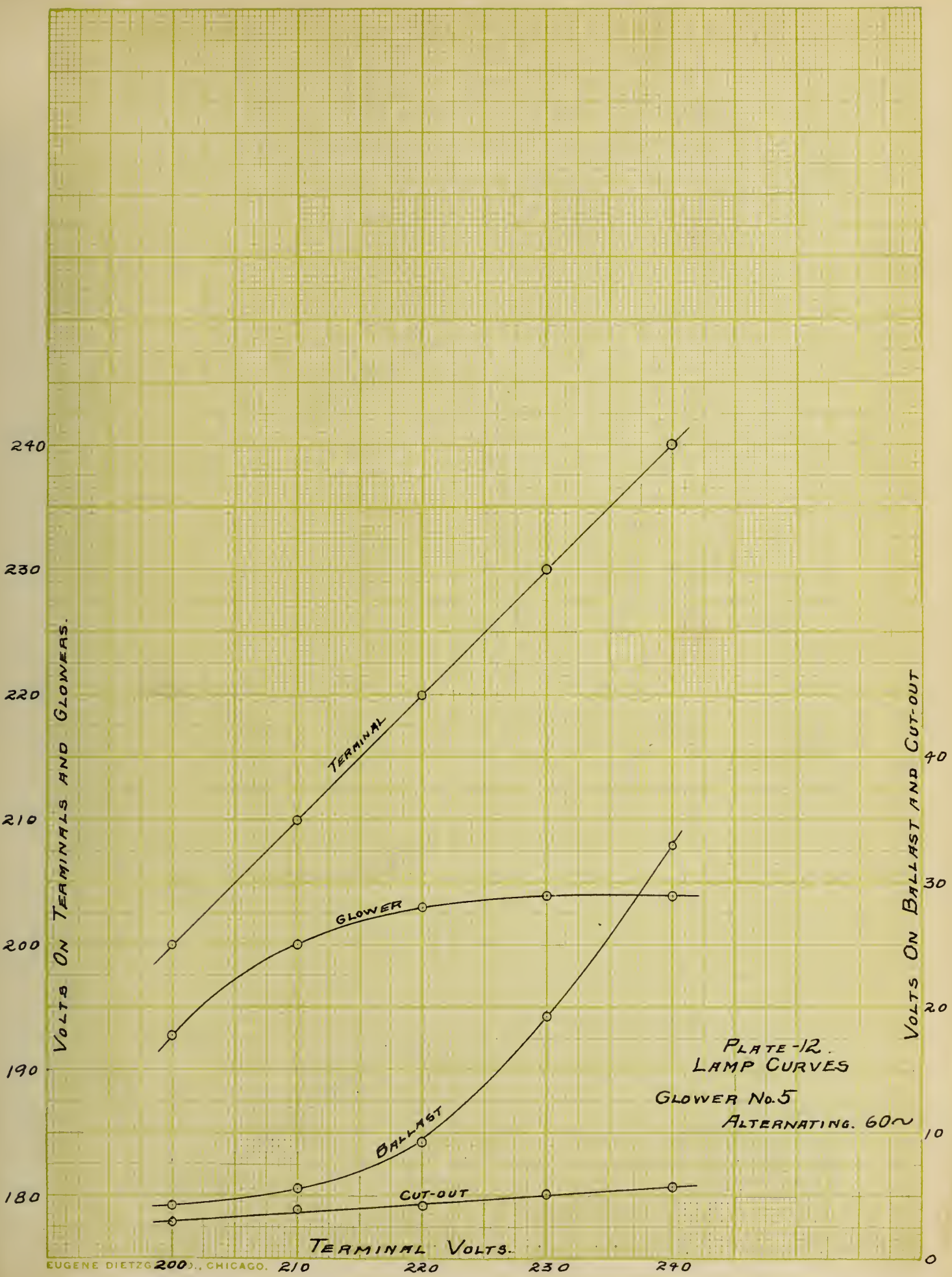




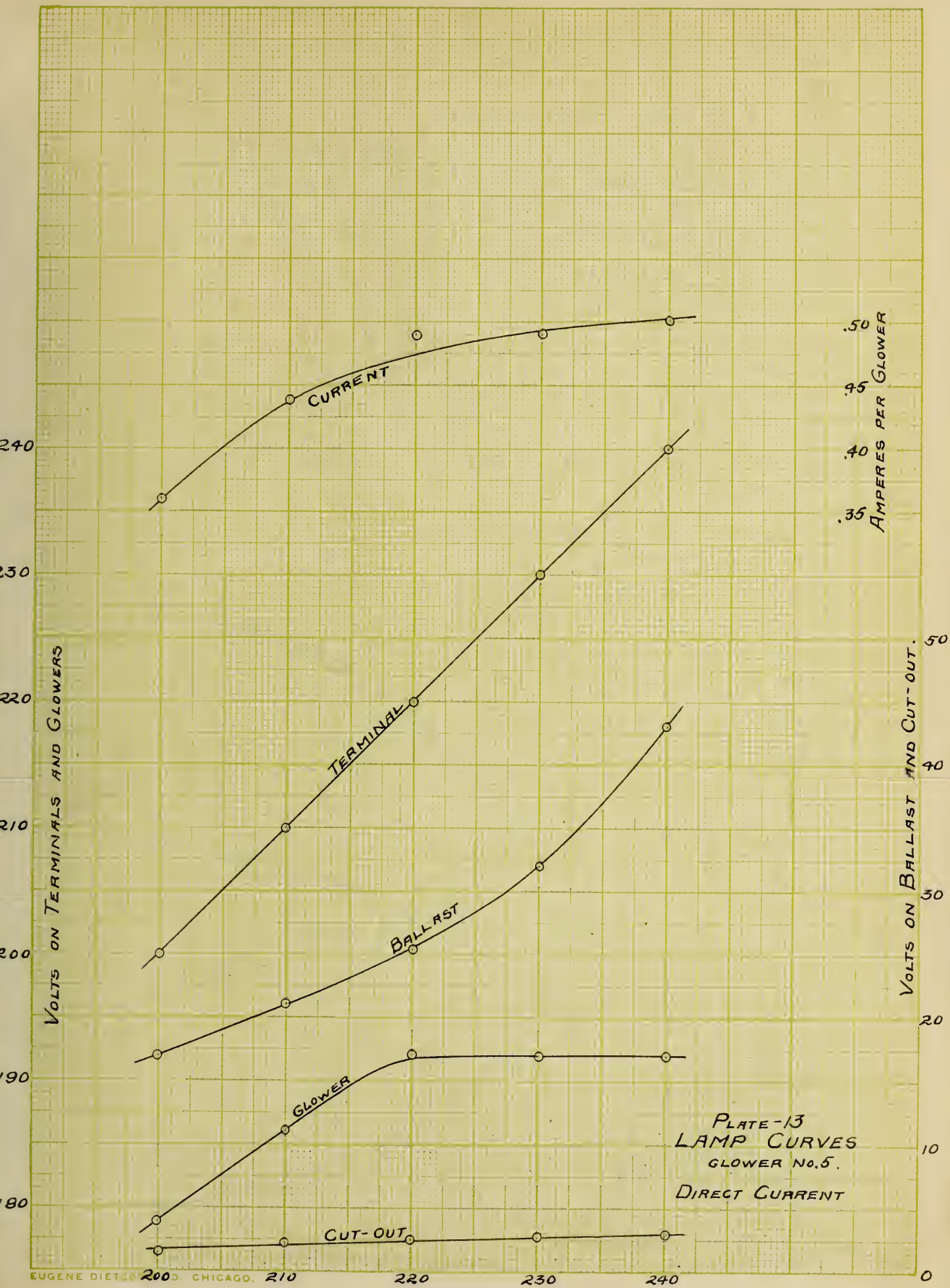


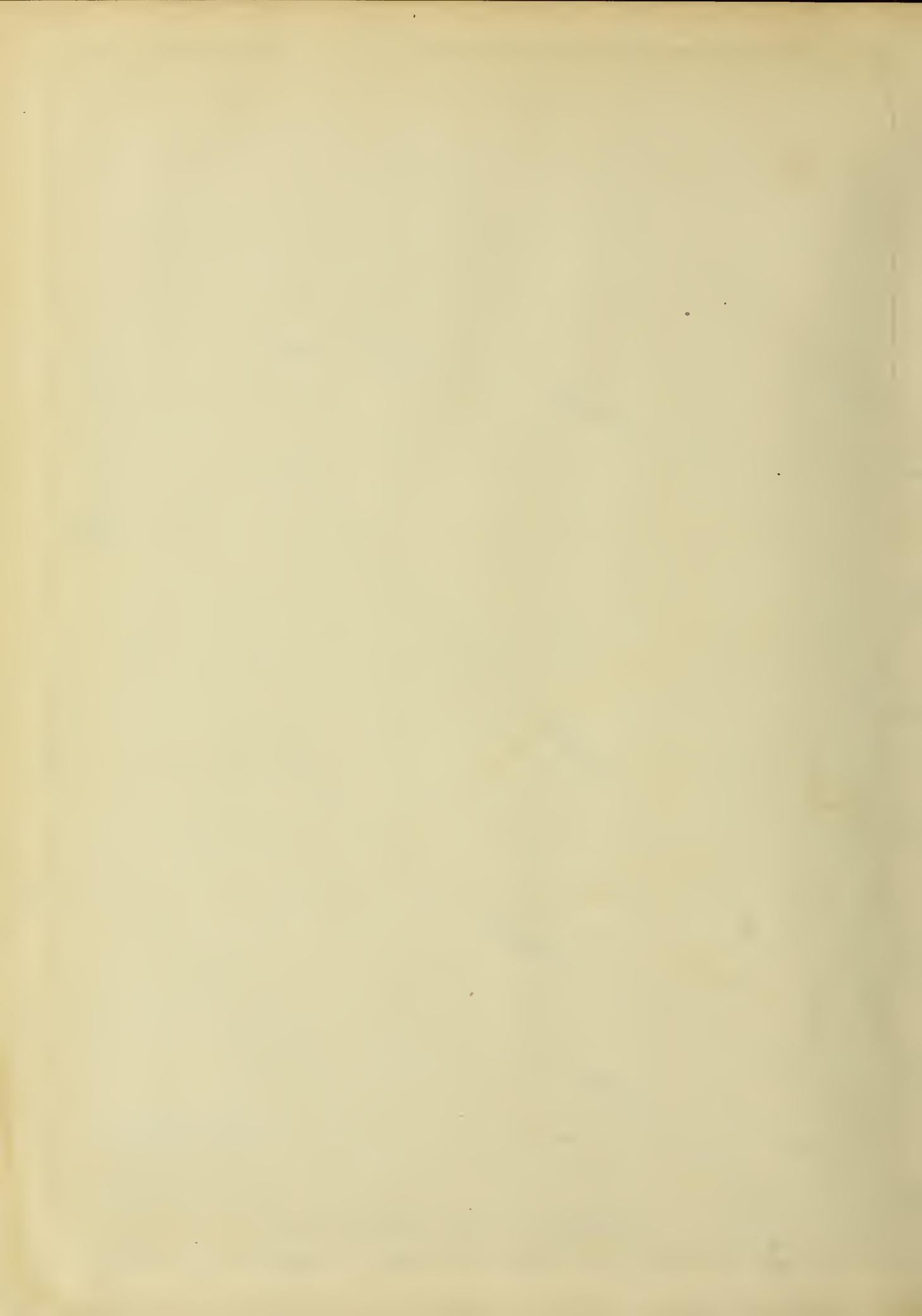












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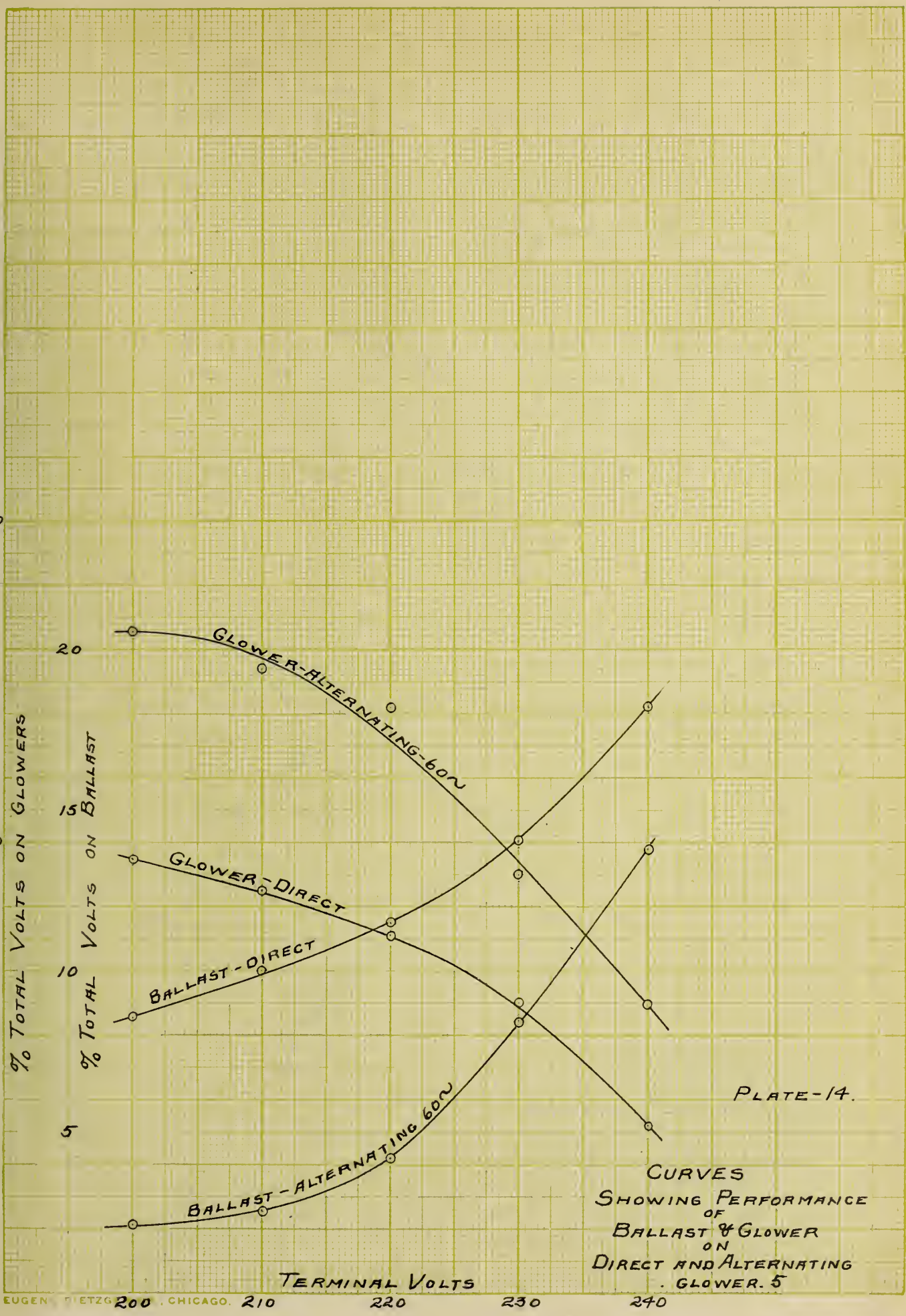
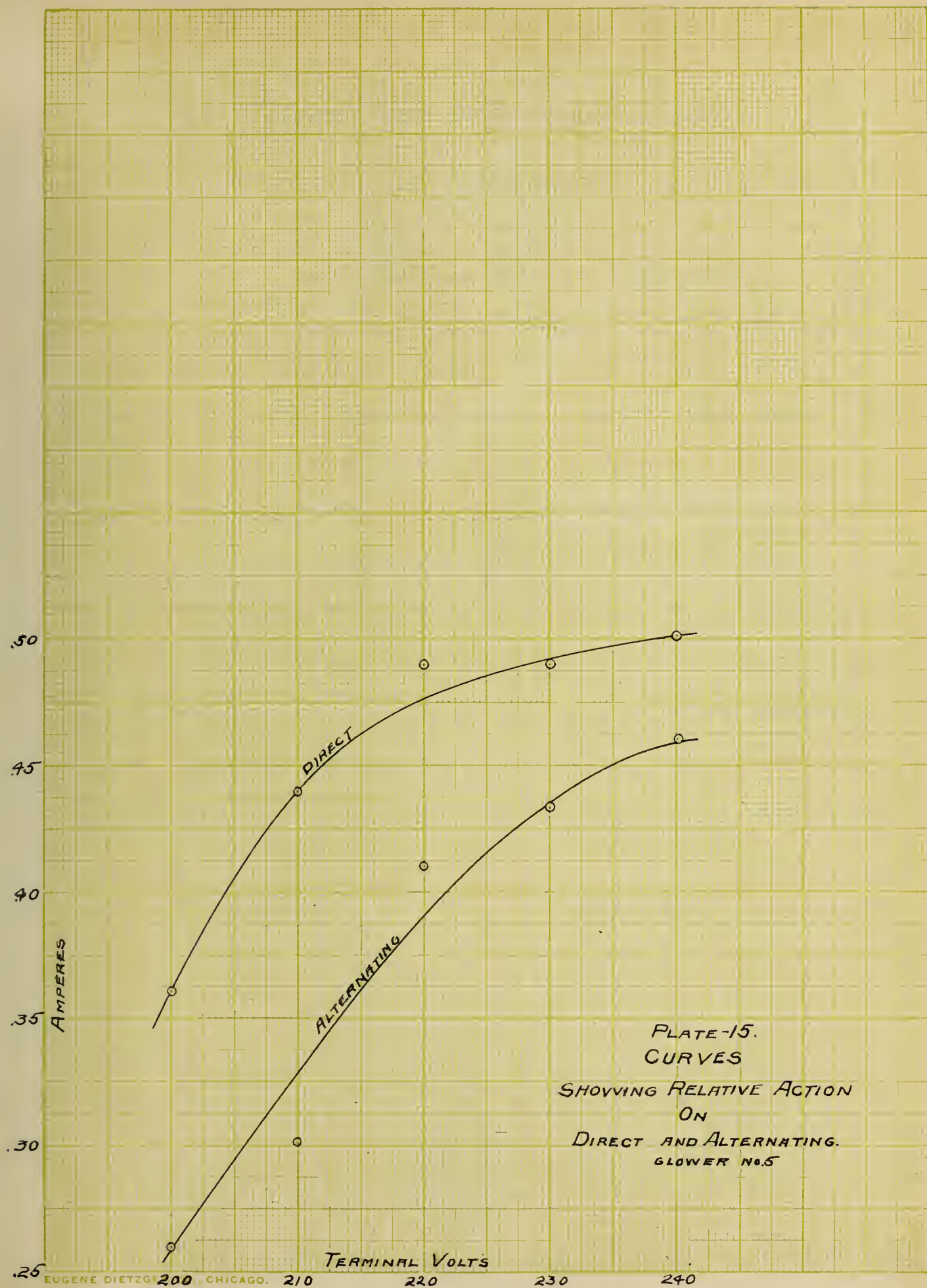


PLATE-14.

CURVES
SHOWING PERFORMANCE
OF
BALLAST & GLOWER
ON
DIRECT AND ALTERNATING
GLOWER. 5





LIFE TEST OF NERNST LAMP

GLOWER NO.3.

E.	I.	W.	HORIZONTAL			VERTICAL			HRS.
			D.	C.P.	W. PER.C.P.	D.	C.P.	W. PER.C.P.	
224	121	257.5	131.2	67.1	3.85	114.5	99	2.01	
224	.775	170.	158.5	37	4.6	137.7	58.2	2.91	48.5
224	.76	169.5	171.5	28.5	5.95	144.5	50.	3.4	19.
224	.755	169.5	173.	27.5	6.16	149.	45.5	3.7	44.
224	.744	164.	172.	28.	5.85	147	47	3.5	64.5
224	.759	162.2	172.7	27.6	5.9	148	46.5	3.5	41.5
224	.755	164.5	167.5	30.6	5.4	147.	47.	3.5	44.
224	.754	162.2	174.5	26.6	6.1	151.5	43.2	3.75	118
224	.75	164.5	164.5	32.6	5.05	150	44.5	3.7	43.5
224	.748	162	172.2	27.7	5.85	156.5	38.6	4.2	98.

LIGHT DISTRIBUTION, VERTICAL.
WITH
OPAL GLOBE.

ANGLE	D	C.P.	E	I	W
0°	159.5	36.5	224	1.16	256
-10°	166.5	31.4	224	1.16	256
15°	175.5	26.2	224	1.16	256
-20°	186.	21.2	224	1.16	256
10°	149.5	45.	224	1.16	256
20°	131.7	66.5	224	1.16	256
30°	121.5	80.5	224	1.16	256
40°	118.5	90.5	224	1.16	256
50°	112.5	104.3	224	1.16	256
60°	113.7	102.	224	1.16	256
75°	116.	96	224	1.16	256
90°	119.7	88	224	1.16	256

LIGHT DISTRIBUTION, VERTICAL.

WITH

HOLOPHANE GLOBE

ANGLE	D	C.P	E	I	W
25°	157.5	38	224	1.16	256
20°	156.5	37.6	224	1.16	256
15°	152	42.5	224	1.16	256
10°	135	63.2	225	1.16	256
0°	125.7	76.5	224	1.16	256
10°	120.5	86.	224	1.16	256
20°	121.	85	224	1.16	256
30°	131	67.5	224	1.16	256
40°	136	60.2	224	1.16	256
50°	146	56.	224	1.16	256
60°	147.5	47.	224	1.16	256
75°	152.5	42.	224	1.16	256
80°	139.5	56	224	1.16	256
90°	133.5	64	224	1.16	256

*LIGHT DISTRIBUTION, VERTICAL
WITHOUT GLOBE.*

<i>ANGLE</i>	<i>D</i>	<i>C.P</i>	<i>E</i>	<i>I</i>	<i>W</i>
0°	127.5	73.2	224	1.25	256
10°	125.	77.	224	1.25	256
15°	153.7	41.5	224	1.25	256
20°	134.5	62.	224	1.25	256
-10°	123.2	79	224	1.25	256
-20°	106.8	120.5	224	1.25	256
-30°	106.	120.5	224	1.25	256
-40°	106.5	121.5	224	1.25	256
-50°	102.	140	224	1.25	256
-60°	101.	140	224	1.25	256
-70°	99.5	148	224	1.25	256
-80°	100.5	140	224	1.25	256
-90°	100.2	141	224	1.25	256



LIGHT DISTRIBUTION, HORIZONTAL
OPAL GLOBE, STARTING $\perp$ TO GLOWERS
GLOWER No. 2.

POSITION	E	I	W	D	C.P.
0°	224	1.15	254	146	48.5
30°	"	"	"	158.5	37
60°	"	"	"	184	22
90°	"	"	"	186.5	21
120°	"	"	"	158.	37.5
150°	"	"	"	146	49
180°	"	"	"	148	46.5
WITH HOLOPHANE GLOBE					
0°	224	1.15	254	126.5	74.5
30°	"	"	"	125.5	77
60°	"	"	"	138	57.5
90°	"	"	"	150	44.5
120°	"	"	"	146	48.2
150°	"	"	"	136.5	59.5
180°	"	"	"	130.5	68

LIGHT DISTRIBUTION, HORIZONTAL

WITHOUT GLOBE, STARTING $\perp$ TO GLOWERS

GLOWER NO. 2.

POSITION	E	I	W	D	C.P.
0°	224	1.15	254	135	61.5
30°	"	"	"	141	54
60°	"	"	"	160	36
75°	"	"	"	240	7.1
90°	"	"	"	—	0.
105°	"	"	"	230.5	8.6
120°	"	"	"	172.5	27.5
150°	"	"	"	140.	55.
180°	"	"	"	130.5	68



LIGHT DISTRIBUTION, AT 45°
HOLOPHANE GLOBE, STARTING $\perp$ TO GLOWERS.

POSITION	E	I	W	D	C.P.
0°	224	1.15	254	140	55
30°	"	"	"	138.5	57
60°	"	"	"	137.5	58.2
90°	"	"	"	138	57.2
120°	"	"	"	139.5	56
150°	"	"	"	140	55
180°	"	"	"	137.5	58.2
WITHOUT GLOBE					
0°	224	1.15	254	106	122.5
30°	"	"	"	110	111
60°	"	"	"	114	101
90°	"	"	"	121.5	84
120°	"	"	"	114.5	99
150°	"	"	"	108.5	115
180°	"	"	"	106	122.5
WITH OPAL GLOBE					
0°	224	1.15	254	113.5	102
30	"	"	"	115	98.5
60°	"	"	"	117	93.5
90°	"	"	"	122.5	82
120°	"	"	"	122	83
150°	"	"	"	123	81
180°	"	"	"	114.5	99

MEAN LOWER HEMISPHERICAL CANDLE-POWER. NERNST LAMP.

AZIMUTH DEGREES		0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
0°	C.P.	52	45	30	29	26	39	45	41.5	29	18	26	39.5	43
		0°	45°	90°	135°	180°	225°	270°	315°	360°				
30°	C.P.	81	67	56	69	77	66	47	62	74				
		0°	90°	180°	270°	360°								
60°	C.P.	91	78	79	76.5	90								
		0°												
90°	C.P.	75.5												

M.L.H. C.P. = 56.



TOTAL EFFICIENCY

BEING THE RATIO, $\frac{\text{LIGHT ENERGY}}{\text{TOTAL ENERGY}}$

GLOWER No. 2.

WITH GROUND GLASS GLOBE

CONDITION	E	W	GALV. DEFLECTION	RATIO $\frac{L}{T}$
L	220	196	1	.0239
T	"	196	72.6	
L	220	241	1.8	.0365
T	224	241	85.6	
L	224	262	2.3	.043
T	224	262	92.4	
L	230	276	2.85	.051
T	230	276	108.5	
SAME WITHOUT GLOBE				
L	210	196	1.7	.0345
T	210	196	85.2	
L	220	241	2.6	.044
T	220	241	102	
L	230	276	3.15	.0445
T	230	276	122.7	

NOTE, JAR OF WATER PASSED 57.8 % LIGHT ENERGY.

TOTAL ENERGY DEF. TO BE INCREASED 3 FOLD. RESISTANCE WAS
USED IN GALVANOMETER CIRCUIT.



STARTING CURRENT. NERNST LAMP.
GLOWER NO. 6.

VOLTS. D.C.	TIME, SEC.	AMPERES.
220	0	.93
220	5	.77
220	10	.69
220	15	.65
220	20	.63
220	25	.63
220	30	.63
220	35	.63
220	40	.66
220	45	.86
220	50	.72
220	55	.90
220	60	1.00
220	65	1.04
220	70	1.07
220	75	1.07



VARIATION OF CANDLE-POWER AFTER LIGHTING
WITH FROSTED GLOBE, 45°
GLOWER No. 2.

<i>E</i>	<i>I</i>	<i>W</i>	<i>D</i>	<i>C.P.</i>	<i>TIME IN MINUTES</i>
224	1.285	280	102.5	132	0
"	1.245	268	105	126	1
"	1.21	264	108.5	115	1
"	1.207	262.5	109.5	112.5	1
"	1.19	260	111.5	107.5	2
"	1.185	255	111.0	108	2
"	1.175	255	111.0	108	4
"	1.175	255	111.0	108	4



VARIATION OF CANDLE-POWER WITH VOLTAGE

TAKEN AT 45°; GROUND GLOBE

GLOWER NO.5.

E	I	W	D	$C.P.$	$\frac{C.P.}{PER}$ GLOWER	$\frac{I}{PER}$ GLOWER	$\frac{W}{PER}$ GLOWER	$\frac{W}{PER}$ C.P.
240	1.3	331	119	164.5	54.8	.43	110	2.02
230	1.26	294	133	120	40	.422	98	2.45
220	1.078	239.5	147	88	29.3	.359	79.8	2.73
210	.887	192	166	59	19.6	.296	64	3.25
200	.745	154	185.5	39.5	13.2	.248	51	3.90

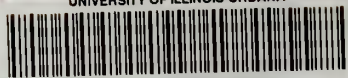
VARIATION OF VOLTAGE ON DIFFERENT PARTS

	E_T	E_G	E_B	E_{C-O}	I	$I_{PER.G.}$	$\% E_T$ ON G	$\% E_T$ ON B
ALTERNATING-60 $\sim$	200	192.8	4.22	2.9	.785	.261	96.5	2.11
	210	200	5.5	3.48	.91	.303	95.4	2.52
	220	203	9.25	4.18	1.24	.403	92.2	4.2
	230	204	19.4	5.09	1.3	.436	89	8.41
	240	204	33	5.7	1.4	.46	85	13.8
DIRECT	200	179	8.2	1.73	1.08	.36	89.5	8.5
	210	186	15.8	2.16	1.33	.44	88.5	10
	220	192	25.3	2.5	1.47	.49	87.1	11.5
	228	192	32.0	2.61	1.48	.493	85.	14
	239	192	43.5	2.84	1.51	.503	81.2	18.2





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